Annals of Medical Research
DOI: 10.5455/annalsmedres.2019.05.291 2019;26(8):1545-50

Original Article

Smear layer removal efficiency of Er,Cr;YSGG and Er:YAG lasers in root canals prepared with different NiTi File systems

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Abstract

Aim: Evaluation of the root canal dentinal wall by scanning electron microscopy (SEM) in order to verify the presence/absence of smear layer after applying different NiTi file systems and Er:YAG and Er,Cr:YSGG lasers.

Material and Methods: Hundred ninety-two mandibular incisors randomly divided into four groups (n=48). Each group was prepared with one of NiTi files: ProTaper Next, One Shape, Reciproc and Twisted file Adaptive using 5.25% NaOCl irrigation. Each group was then subdivided into four groups (n=12). Er,Cr:YSGG laser, Er:YAG laser and EDTA were separately applied to the first three subgroups. In the control group, no further disinfection protocol was performed. Then the roots were sectioned longitudinally and halves were examined under SEM.

Results: Erbium laser systems removed the smear layer better than NaOCl irrigation, but not as much as EDTA/NaOCl. The greatest reduction in smear was obtained with Reciproc/EDTA and Reciproc/Er,Cr:YSGG groups. The success of irrigation protocols from highest to lowest was EDTA, ErCr: YSGG laser and Er:YAG laser.

Conclusions: Single file NiTi instruments appeared to be more effective than multiple-file systems in leaving clean root canal walls. The reciprocating systems produced less smear layer than rotating instruments. Er:YAG and Er,Cr:YSGG laser activations appeared to be more efficient than syringe irrigation to remove the smear layer.

Keywords: Er,Cr:YSGG laser; Er:YAG laser; NiTi file; SEM; smear layer.

INTRODUCTION

It is important to promote techniques and products that can prevent the formation of a smear layer and simplify its elimination. Debris removal and smear layer production of different rotary systems vary because of variations in system design and kinematics (1). Protaper Next file system manufactured by M-wire technology affords more cross-sectional space for enhanced cutting, loading, and augering of debris; and also allows cutting a bigger envelope of motion compared to a similarly-sized file with asymmetrical mass and axis of rotation (2,3). Jadhav et al. (4) pointed out that Protaper Next system has a better potential for debris and smear layer removal compared to ProTaper due to its offset mass of rotation which allowed two pointed contact of the file to the canal at a time that reduced debris with improved canal cleaning ability. One Shape is made of conventional austenite alloy and is used in full clockwise rotating motion and only one file is required for the complete shaping of the root canal. In pecking motion instrument allows movement of debris upward (5). Dagna et al. (6) evaluated debris accumulation after use of One Shape, Sky Taper, Wave One, Reciproc and have found that continuous rotation appeared to be more effective than reciprocating instruments in leaving clean walls. TF Adaptive (Sybron-Endo, Orange, CA, USA) is manufactured from R-Phase NiTi and was designed with the goal of taking advantage of both a reciprocating instrument and rotary one. The interrupted motion of files in lateral cutting allows optimal brushing and circumferential filing for better debris removal in oval canals. TF Adaptive instrument is working for a longer time with a CW angle

Received: 27.05.2019 **Accepted:** 21.06.2019 **Available online:** 05.08.2019
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which allows better cutting efficiency and removal of debris because the flutes are designed to remove debris in a CW rotation. A Reciproc instrument manufactured from M-wire operates with reciprocal motion. Amaral et al. (7) have found that Reciproc, WaveOne, and Mtwo instruments were effective in smear layer removal mainly in the middle and coronal thirds without significant differences among them. Despite controversial findings, none of the systems yielded root canals completely free from packed hard tissue debris and smear even after instrumentation and agitated irrigation (8).

Use of a laser to remove the smear layer and disinfect root canals has been subject of interest. Takeda et al. (9) have shown that lasers can remove smear layer by vaporizing tissues in the canals. Different lasers such as Nd: YAG, CO2, Er:YAG and Er,Cr:YSGG have been used for debris and smear removal from the root canals. In addition, different laser wavelengths have been used directly as an adjunctive to disinfect canals. It appears that erbium lasers because of their effect on minerals existing in debris and smear layer can be more effective in removing these two components from the root canals (10).

The purpose of this study was to evaluate the amount of smear layer on canal walls following the use of different NiTi rotary systems and adjunct use of Er:YAG and Er,Cr:YSGG lasers.

MATERIAL and METHODS

Sample collection

Two hundred single-roots of human mandibular incisor teeth with straight canals were selected for the study. All calculus and soft tissue remnants were removed from the root surfaces using ultrasonic scalers and stored in sterile saline solution after disinfected in thymol solution at room temperature.

Inclusion criteria (n=192)

Teeth with straight and single patent root canals with completely formed apices free of any anatomical variation confirmed by buccal and proximal radiographs.

Exclusion criteria (n)=8

Teeth with visible root caries, signs of external and internal resorption, cracks or fracture lines viewed under operation microscope with x16 magnification were excluded.

Teeth preparation for the study

All the teeth were decoronated using a diamond disc (DZ, Darmstadt, Germany) until 12 mm long roots were obtained. The coronal access cavity was prepared with high-speed burs and all canals were checked for apical patency with K-file (015/02; Mani, Japan). Working length was obtained by measuring the length of the initial instrument at apical foramen minus 1 mm. The apices of the roots were sealed with wax to avoid the extrusion of irrigants and debris. The samples were randomly divided into 4 groups according to the file system used for the preparation of root canals as follows:

Group 1 (n=48) (ProTaper Next Group, Dentsply Maillefer, Ballaigues, Switzerland): Root canals were instrumented with SX-X1 and sequentially followed by X2 instruments used with endodontic motor (Xsmart, Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer's recommendations (300 rpm, 2.0 Ncm).

Group 2 (n=48) (One Shape Group, Micro-Mega, Besançon, France): Root canals were instrumented with size 25, 0.06 tapered file according to the manufacturer's recommendations until the working length was reached.

Group 3 (n=48) (Reciproc Group, VDW GmbH, Munich, Germany): Roots were prepared with an R25 Reciproc instrument attached to endodontic motor set to 'RECIPROC ALL' mode. The file was inserted through the root canal and used with pecking motions. Preparation was ended when the working length was reached.

Group 4 (n=48) (Twisted File Adaptive Group, SybronEndo, Glendora, CA, USA): Roots were prepared with SM1-SM2 instruments of Twisted File Adaptive system which correspond to 20/04 and 25/06 respectively. A special endodontic motor (Elements motor, SybronEndo, Glendora, CA, USA) which is able to work with the mode of Adaptive motion.

Each root canal was irrigated with 10 ml 5.25% NaOCl during the entire preparation process. Then, samples of each file group were randomly divided into 4 subgroups (n=12) according to the final irrigation and/or irradiation protocol;

Er,Cr:YSGG laser group: Er,Cr:YSGG laser (Waterlase, Biolase, San Clemente, CA) was used at "Clean and Shape" mode by using 21 mm long 200 µm diameter Radial Firing Tip. The settings were 2780 nm wavelength, 1.25 w output power, 50 Hz frequency, 140 µs pulse length, 34% air and 24% water. The tip was inserted up to 1 mm short of working length while the canal was filled with NaOCl. It was withdrawn with a speed of 1 mm/s by using a circular motion. This was repeated 4 times.

Er:YAG laser group: Root canals were filled with NaOCl. Er:YAG laser device's (AT Fidelis, Fotona, Ljubljana, Slovenia) R14-C-759 handpiece equipped with 14 mm long, 300 µm tip (Preciso 300/14, Fotona, Ljubljana, Slovenia) was employed for this group. The tip was inserted into canal up to 5 mm from canal orifice. Irrigation with NaOCl and laser activation was performed simultaneously for 5 seconds. This was repeated 4 times. Laser parameters were 2940 nm wavelength, 1 w output power, 20 Hz, 50 mJ and 50 µs pulse length.

EDTA group: Root canals were rinsed with 17% EDTA solution (Henry Schein Inc., Melville, USA). The needle tip was inserted into root canals 1 mm short of working length. Irrigation was applied 60 seconds with 5 ml EDTA solution per canal.

Control group: No further irrigation and irradiation were applied.

All root canal preparations were performed by one operator to maintain the uniformity. Details of the study were presented in Figure 1.

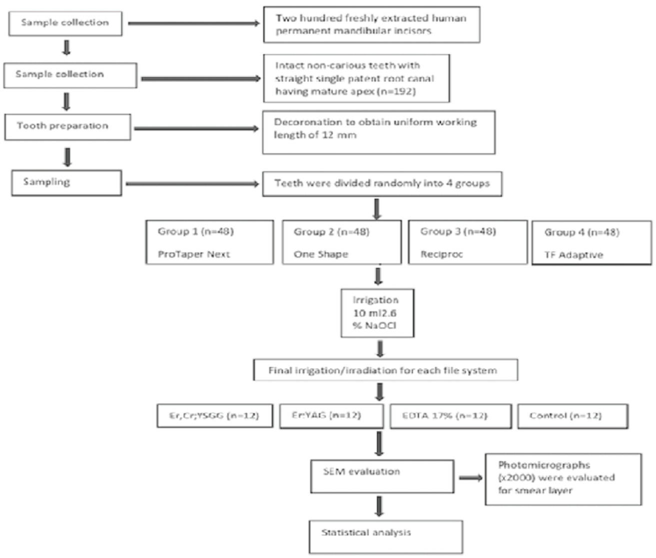

Figure 1. Flowchart of the study

Scanning electron microscopy analysis

After completion of the preparation procedure, the teeth were sectioned longitudinally. Grooves were prepared on the buccal and lingual surfaces with a 0.19 mm thickened discs (Horico SH 394C190). Then, the roots were split into 2 halves with hammer and chisel.

All samples were kept in 50%, 75% and 85% ethyl alcohol respectively and left for drying. Inner surfaces of the root halves were coated with 90 Angstrom (A°) thickened gold-palladium alloy (Emitech Sputter Coater, Emitech Limited, Ashford, UK). Then, all surfaces were examined under SEM (JSM- 6390, Jeol ABD Inc., Massachusetts, USA) with a magnification of x2000 for the presence of smear layer on apical, coronal and middle thirds.

Smear scores were recorded according to a 5-degree scale stated by Hülsmann et al. (11);

•Score 1: No smear, tubules are totally open.

•Score2: Minimal smear, most of the tubules are open.

•Score 3: Homogenous smear layer covering the root surface, most of the tubules are closed.

•Score 4: All root surfaces are coated with the smear layer. No tubules are open

•Score 5: All root surfaces are coated with an intense and tight smear layer.

Two endodontists (who were not involved in the study) were trained to interpret the photomicrographs by rigorous; multiple training sessions until consensus was reached between them. The photomicrographs were interpreted by both trained endodontists independently and jointly to arrive at a consensus. The findings were entered into an Excel sheet (Microsoft, Seattle, WA). To cross-check for further intrinsic interobserver variability, each of the photomicrographs was analyzed for the second time 1 week after the initial examination by the same endodontist.

Statistical analysis

Intra-class correlation modules were calculated for consent between the two observers. Main groups were compared with 3-way factor variance analysis while subgroups were compared by using LSD multi-comparison test. Statistical Package for the Social Sciences for Windows version 24.0 (IBM SPSS Corp.; Armonk, NY, USA) software package was used for statistical analyses. A significance level of 0.05 used for all statistical tests.

RESULTS

The results of the smear layer scores are presented in Table 1. Regarding the total mean scores, all shaping instruments left a smear on the dentine and use of EDTA and erbium lasers were unable to produce smear free surfaces. All study groups represented an increase in smear presence from coronal to apical ($p<0.05$). In a comparison of instrument systems with syringe irrigation, TF group yielded a better result than ProTaper Next in the coronal region ($p<0.05$). However, ProTaper Next group was better than the TF group in mid-root level ($p<0.05$). No difference was found between OneShape and Reciproc groups for both coronal and middle root levels ($p>0.05$). There was no difference among groups in the apical region ($p>0.05$).

Table 1. Means and Standard Deviation (SD) Score Values of the Smear Layer for Irrigation/Irradiation Techniques

Group	Coronal	Middle	Apical
PTN1	$4.83\pm0.24^{a,A}$	$3.96\pm0.49^{a,B}$	$4.58\pm0.51^{a,A}$
OS1	$4.63\pm0.48^{a,A}$	$4.50\pm0.52^{a,A}$	$4.50\pm0.52^{a,A}$
RE1	$4.33\pm0.49^{a,A}$	$4.42\pm0.51^{a,A}$	$4.50\pm0.52^{a,A}$
TF1	$4.17\pm0.38^{b,A}$	$4.58\pm0.51^{b,A}$	$4.75\pm0.45^{a,A}$
PTN2	$2.29\pm0.86^{c,A}$	$3.21\pm0.70^{c,B}$	$3.50\pm0.90^{b,B}$
OS2	$2.21\pm0.94^{c,A}$	$2.38\pm1.18^{d,A}$	$4.04\pm0.33^{b,B}$
RE2	$2.08\pm0.90^{c,A}$	$2.46\pm0.98^{d,A}$	$3.21\pm0.58^{c,B}$
TF2	$2.00\pm0.95^{c,A}$	$2.71\pm0.68^{d,B}$	$3.67\pm0.49^{b,C}$
PTN3	$2.87\pm0.80^{d,A}$	$3.58\pm0.60^{c,a,B}$	$3.92\pm0.28^{b,B}$
OS3	$2.21\pm1.30^{c,A}$	$3.25\pm0.96^{c,d,B}$	$3.75\pm0.45^{b,B}$
RE3	$2.42\pm0.66^{d,c,A}$	$2.92\pm0.79^{d,B}$	3.83 ± 0.71^{b}C
TF3	$2.88\pm1.09^{d,A}$	$2.83\pm1.03^{d,A}$	$3.71\pm0.86^{b,B}$
PTN4	$1.96\pm0.54^{c,A}$	$2.46\pm0.65^{d,B}$	$3.88\pm0.76^{d,b,C}$
OS4	$1.92\pm0.51^{c,A}$	$2.67\pm0.65^{d,B}$	$2.75\pm0.86^{e,B}$
RE4	$1.67\pm0.88^{c,A}$	$2.42\pm0.66^{e,d,B}$	$3.25\pm0.62^{d,c,C}$
TF4	$2.08\pm0.51^{c,d,A}$	$3.00\pm0.85^{f,c,B}$	$3.08\pm0.66^{d,c,B}$

Data with different lowercase letters (a, b, c, d, e, f) indicate significant differences within each row and data with different uppercase letters (A, B, C) indicate significant differences within each column (p<.05). Data presented are the percentage area of the root canal wall in the coronal, middle and apical third regions occupied by patent dentin tubules from N=12 samples per group. PTN=ProTaper Next;OS=neshape; RE= Reciproc; TF=Twisted File Adaptive; 1= Control; 2=Er.Cr;YSGG Laser; 3=Er.YAG Laser; 4=EDTA

For evaluation of irrigation techniques, EDTA and erbium laser systems were more efficient than the control group for removal of smear ($p<0.05$). There was no difference for Er,Cr:YSGG and EDTA groups for coronal level ($p>0.05$) (Figure 2).

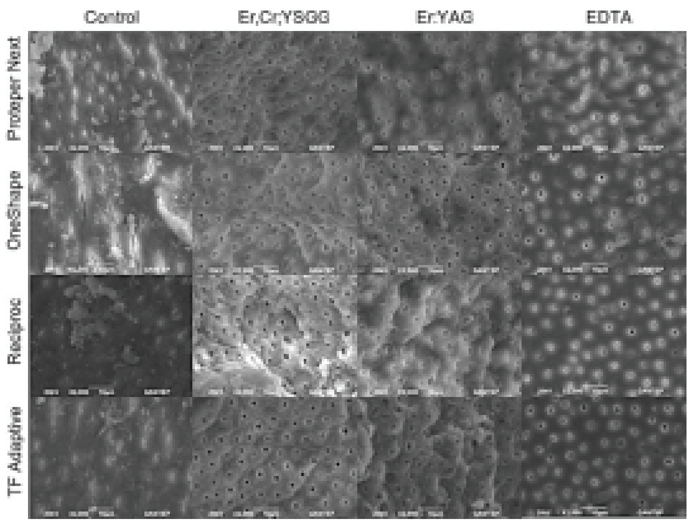

Figure 2. Representative scanning electron microscopic images showing selected samples from the coronal thirds after treatments (magnification 2000X)

EDTA was more efficient than the other groups in the middle root level ($p<0.05$) (Figure 3). There was no difference in the apical region between the EDTA and erbium laser groups ($p>0.05$) (Figure 4).

In the evaluation of EDTA and laser applications by comparing instrument systems;

In Er,Cr:YSGG application there was no difference between instruments for coronal level ($p>0.05$). In middle root level, other file systems were more efficient than ProTaper Next, however, no difference was found between them ($p<0.05$). In the apical region, Reciproc and ProTaper Next instruments were more efficient than OneShape ($p<0.05$).

In Er: YAG application, One Shape and ProTaper Next were significantly more efficient than TF at the coronal level ($p<0.05$). Reciproc and TF were more efficient than ProTaper Next at the middle root level ($p<0.05$). There was no difference at the apical level between the instrument systems ($p>0.05$.

In EDTA application no difference was found among instruments at coronal, however, Reciproc group was more efficient than TF at the middle root level ($p<0.05$). At apical OneShape was more efficient than ProTaper Next ($p<0.05$). In a comparison of irrigation techniques for different instruments, least smear scores were obtained in EDTA used Reciproc group in both coronal and middle root levels. However, there was no difference between EDTA and laser groups. In Reciproc group Er,Cr:YSGG and EDTA were more effective than Er:YAG laser group at apical level ($p<0.05$).

At TF group no difference was found between Er,Cr:YSGG and EDTA groups and these groups were more efficient than Er:YAG group at the coronal ($p<0.05$). At the middle root level, least scores were found between experiment groups, however, there was no difference between them ($p>0.05$). At apical no difference was found between lasers, however, EDTA was more effective ($p<0.05$).

In OneShape group all the applications were more effective than control at coronal and middle root levels ($p<0.05$). Er:YAG and EDTA applications were more efficient than Er,Cr:YSGG and syringe irrigation with OneShape preparation and EDTA was most effective at apical ($p<0.05$).

In the ProTaper Next group, there was no difference between EDTA and Er,Cr:YSGG groups and these groups were more efficient than Er:YAG group at the coronal level ($p<0.05$). EDTA was significantly more efficient than the other groups at the mid-root ($p<0.05$). There was no difference at apical among the groups ($p>0.05$).

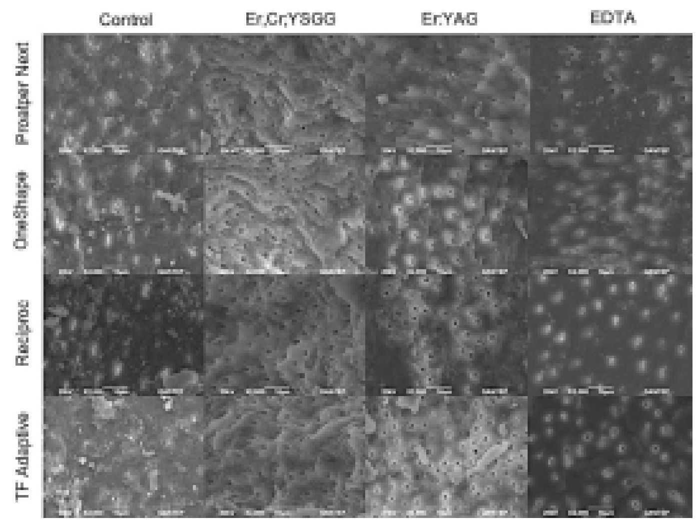

Figure 3. Representative scanning electron microscopic images showing selected samples from the middle thirds after treatments (magnification 2000X)

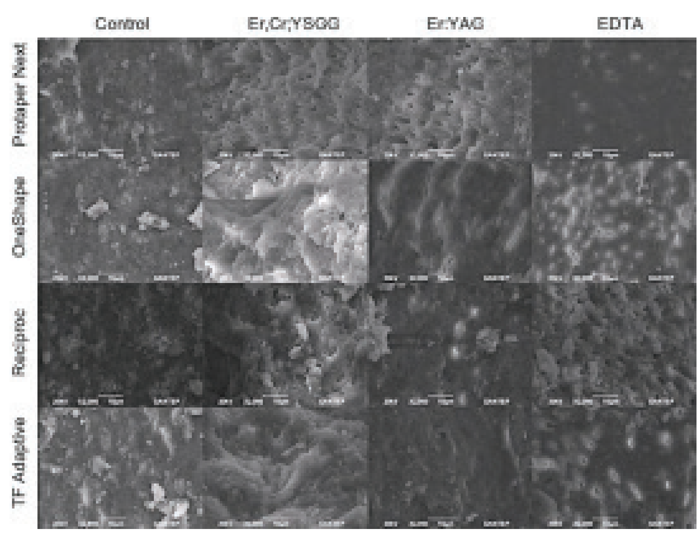

Figure 4. Representative scanning electron microscopic images showing selected samples from the apical thirds after treatments (magnification 2000X)

DISCUSSION

During chemomechanical preparation cutting dentine by using hand or rotary instruments results in producing considerable quantities of debris and smear layer (12). Removal of the smear layer is recommended for disinfection and 3-dimensional cleaning of the root canal system (13,14). The effect of using different types of instruments on tightness and in turn, removability of smear is not clearly stated in previous studies. Thus, the present study aimed to find out any possible effects of different types of instruments and irrigation techniques on smear layer production and removal and subsequently efficiency of adjunct use of laser. Because of production and removal of smear could be affected by the design and motion of the instrument, selection of proper instrument system is crucial. Dentinal walls of root canals demonstrated heavy smear after preparation with ProTaper Next, One Shape, Reciproc and TF Adaptive instruments using syringe irrigation with NaOCl in the present study (Figure 2-3 and 4). Previous studies also concluded that it is difficult to achieve total elimination of the smear layer using needle irrigation by using NaOCl (1,15). Reciproc and TF Adaptive instruments had similar results in the present study and TF Adaptive group have represented fewer smear scores compared to Protaper Next in coronal and mid-root sections. Bürklein et al. (1) evaluated the smear removing the capacity of reciprocating files including Reciproc and WaveOne instruments and compared them with rotating files Mtwo and Protaper. They found that Reciproc and Mtwo are superior to others which may highlight the importance of cross-section geometry besides motion types. However, no difference was found in the apical one-third. On the contrary to our findings, Dagna et al. (6) have found that single-use NiTi systems used in continuous rotation appeared to be more effective than reciprocating instruments in leaving clean walls. The reciprocating systems produced more debris and smear layer than rotating instruments.

Scores obtained for Reciproc and One Shape was very close in the present study. Reciproc and OneShape have S shape cross section and both of them are single file systems. The other used instruments were than multiple-file systems and a TF Adaptive instrument has a triangle cross section and ProTaper Next instruments has offset design. In some specimens, TF was more efficient than ProTaper Next without having any statistical difference. The efficiency of TF Adaptive may be based on its Adaptive motion.

Previous studies stated that (16,17) smear removing can be achieved better in coronal and middle one-third compared to apical one-third in accordance with the results of the present study (Figure 2-3 and 4). According to the researchers, this result may be due to the larger diameter of the canals in the coronal and middle third than the apical region and better contact of the irrigation solutions with dentin.

The present study also evaluated whether using Er:YAG or Er,Cr:YSGG laser for efficient removal of smear layer and to compare EDTA employed for final flush after different NiTi systems used with traditional irrigation using NaOCl. The laser systems removed the smear layer better than the control group, but less than EDTA. Former studies showed that Erbium family lasers including Er:YAG and Er,Cr:YSGG were highly effective in removing smear layer resulting from their action of mechanism which works by ablating water (18,19). However, first tips manufactured for Er,Cr:YSGG lasers did not provide desired results (20,21) and radially irradiating tips were manufactured instead of linear ones to gain more contact with dentinal walls (22). We preferred to use these radial firing tips to obtain better results. Kalyoncuoğlu and Demiryürek (23) evaluated the efficacy of smear layer removal from teeth following root canal treatment using Er:YAG and Nd: YAG lasers compared to NaOCl and concluded that although the improvement was observed in removal of the smear layer, application of EDTA and NaOCl remains an effective technique. This finding is harmonious with those of the present study. When comparing smear removal after use of EDTA and activation of NaOCl with Er:YAG and Er,Cr:YSGG lasers degree of reduction is significantly improved in the present study. Arslan and Aladağ (24) also concluded that by using Er:YAG laser and Nd: YAG laser and comparing with combinations of EDTA/NaOCl and citric acid/NaOCl and only NaOCl (control) all the study groups was better than control, but acid groups were more effective for smear removal. In the study of Altundasar et al. (25) using only NaOCl lead to high smear scores which increase toward apical portion compared to EDTA and Er,Cr:YSGG laser used specimens. In other words, using at least one of chelation solutions agents, Erbium laser or their combination seems necessary to be able to remove smear more efficiently. Guidotti et al. (26) also found that Er:YAG fiber double irradiation with EDTA 17% and NaOCl 2.5% has been demonstrated to be effective in removing the smear layer, even in the apical third. On the contrary, Kıvanç et al. (27) found that Er:YAG and Nd: YAG lasers were not effective in removing debris and smear layer.

Both Er:YAG and Er,Cr:YSGG lasers were more effective in Reciproc subgroups by taking care of both instruments and agitation system. This may possibly be related with 8% taper of Reciproc in apical 3 mm which lead to better contact of laser irradiation with dentine walls in the apical section.

Under the conditions of the present study, 60 seconds application of 17 %EDTA removed smear layer from root canals more efficiently when compared to the control group and also superior to laser-treated groups. However, EDTA and laser systems failed in apical third in the removal of the smear layer. Results for the apical third were compatible with those of the studies that show how uneasy it is to remove the smear layer in that third. Use of 17% EDTA after NaOCl irrigation is the most commonly applied irrigation protocol in the root canal treatment to provide smear layer removal, antimicrobial disinfection, and necrotic tissue dissolution (28). However previous studies revealed that prolonged application of EDTA may result in damage in root dentine (29). Therefore, application of EDTA in all groups is limited within 60 seconds for the present study.

CONCLUSION

Within the limitations of this study, choice single-file systems seem more advantageous compared to multi-file systems in terms of the removability of the smear layer. Better results were obtained with the use of Reciprocal instruments. Syringe irrigation with NaOCl and final irrigation with EDTA was most effective with 1 min application at coronal and mid-root levels and Er:YAG and Er,Cr:YSGG laser activations appear to be more efficient than syringe irrigation with NaOCl to remove the smear layer.

Financial Disclosure: This research, as part of the Doctoral thesis of Dr. Fatih Aksoy, supported by The Scientific and Technological Research Council of Turkey (Project number: 115S160) ‘

Competing interests: The authors declare that they have no competing interest.
Financial Disclosure: This research, as part of the Doctoral thesis of Dr. Fatih Aksoy, supported
by The Scientific and Technological Research Council of Turkey (Project number: 115S160).
Ethical approval: The present study was approved by the Ethical Committee of Gaziantep University (Approval no: 3/2015).

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